Physics of the electroweak sector at CMS

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Introduction

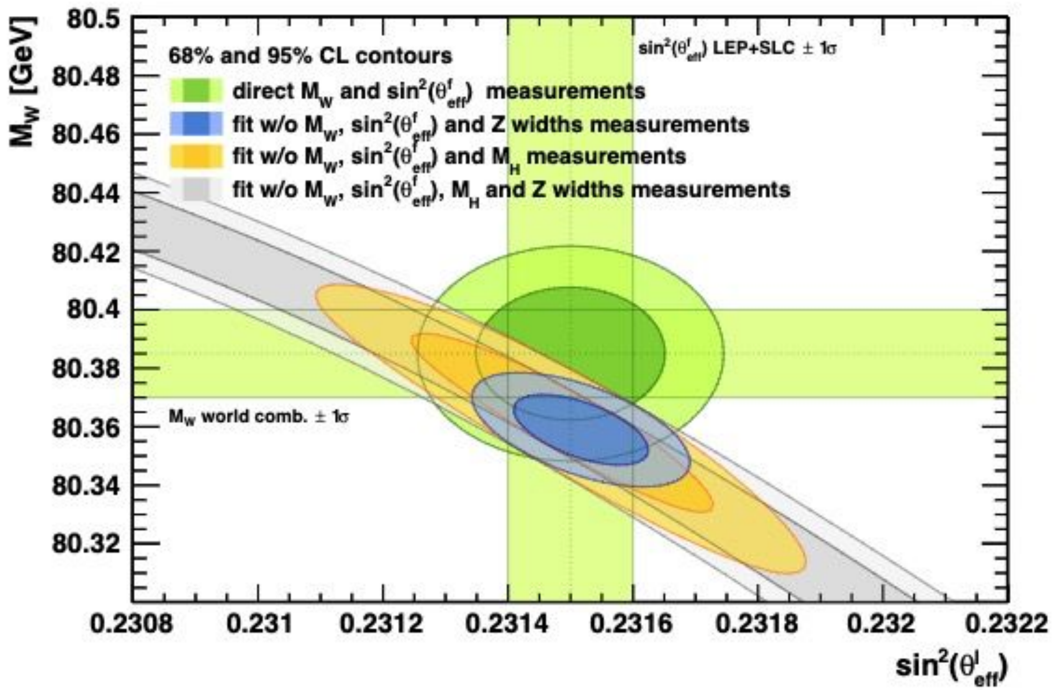
EWK sector one of the most successful and well tested parts of SM

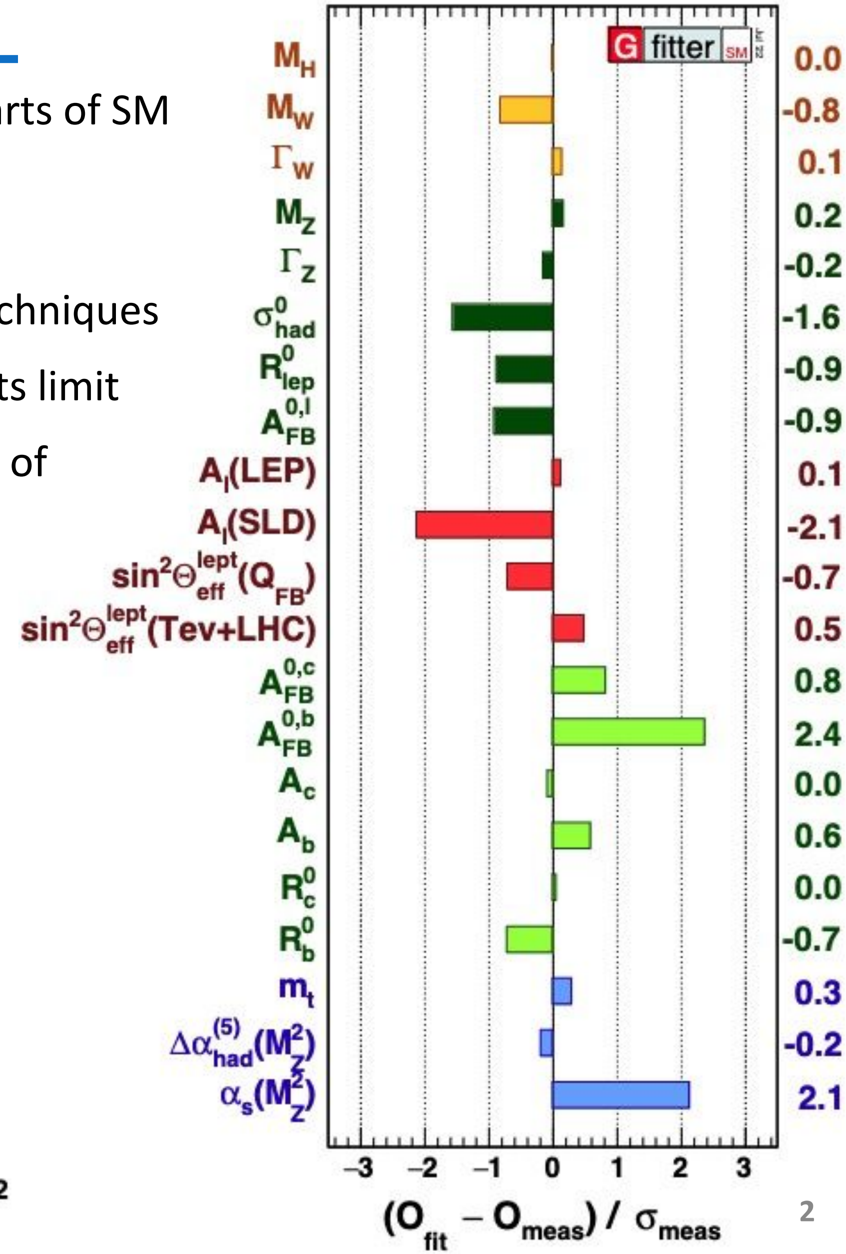
Many inputs from properties of bosons, cross sections, fundamental parameters

→ interplay between different experiments, energies, techniques

LHC can play a fundamental role in testing the theory to its limit

Precision measurements at the O(%) level require control of experimental uncertainties and theory inputs





$\sin^2\theta^{\ell}_{\mathrm{eff}}$

CMS-PAS-22-010

What we measure

Asymmetry in DY lepton decay angular distribution

$$\frac{d\sigma}{d(\cos\theta^*)} \propto 1 + \cos^2\theta^* + A_4 \cos\theta^* \quad \Rightarrow \quad A_{\rm FB} = \frac{3}{8}A_4 = \frac{\sigma_{\rm F} - \sigma_{\rm B}}{\sigma_{\rm F} + \sigma_{\rm B}} \quad \Rightarrow \quad sin^2\theta^l_{eff}$$

Use y_{ll} to define positive direction of incoming quark

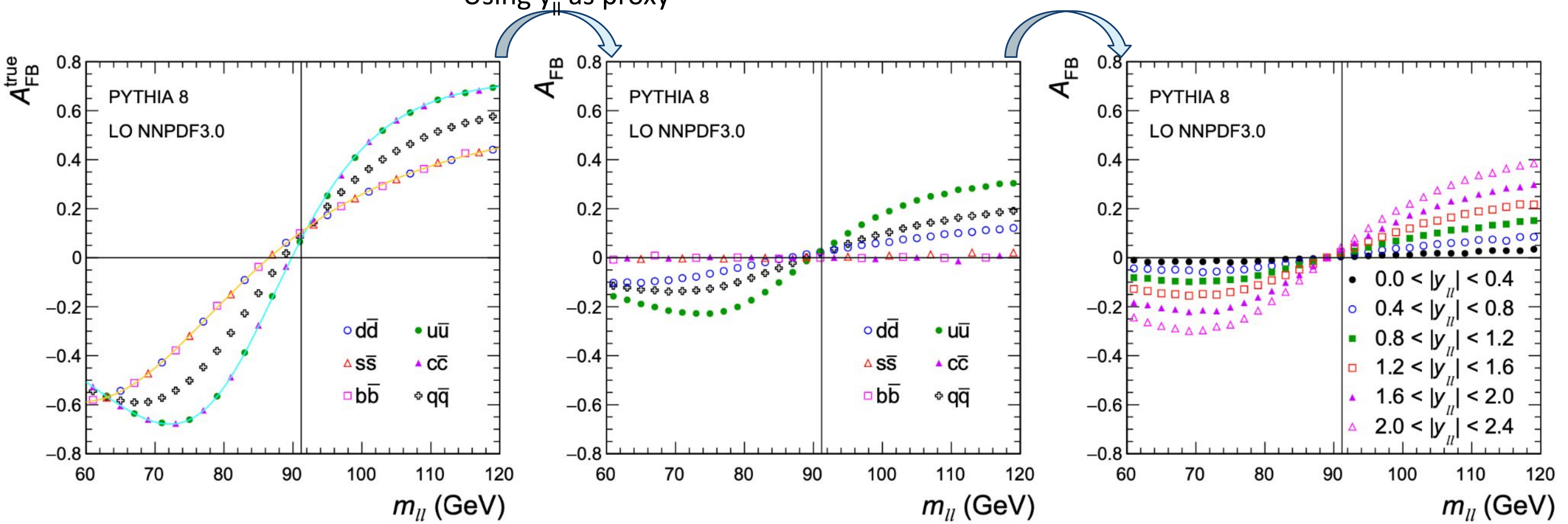
$\longrightarrow$ effect of dilution and PDF uncertainties

$\longrightarrow$ strong dependence of A_{fb} with rapidity

$\longrightarrow$ determine angle from A_{fb} or unfolded A_4

Using y_{ll} as proxy

Using PDFs…



Analysis strategy

Analysis on full run-2 dataset

Four dilepton states:

- $\mu\mu$: $|\eta| < 2.4$
- ee : $|\eta| < 2.5$
- ee_g : fwd electron $2.5 < |\eta| < 2.87$
- ee_h: HF electron $3.14 < |\eta| < 4.36$

$\rightarrow$ maximal extension of acceptance using EM showers in forward calorimeters

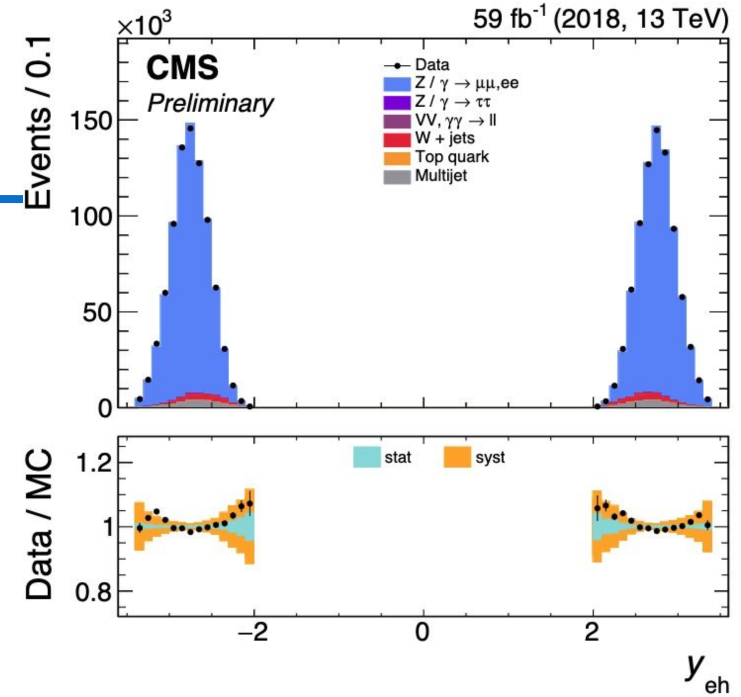
Main backgrounds:

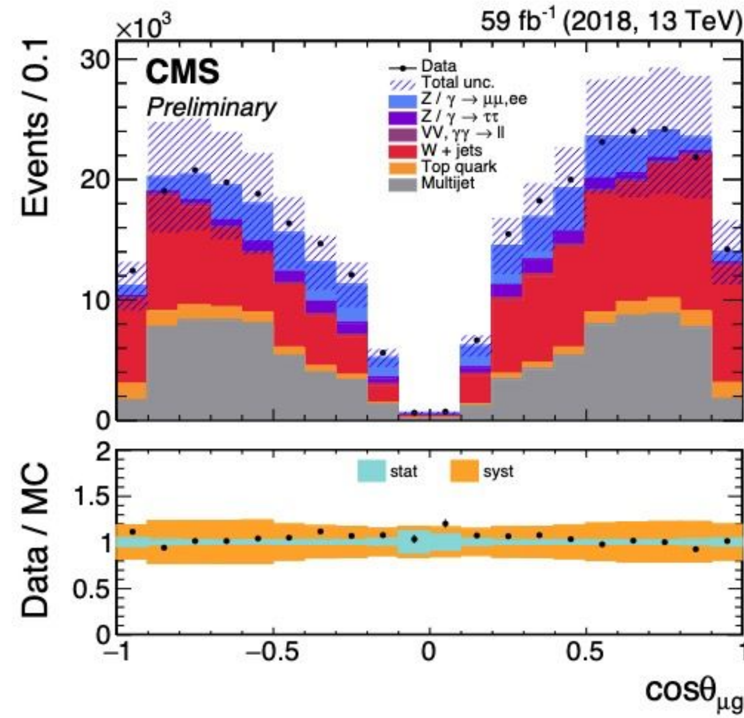
- QCD (from data sidebands)
- W+jets (from simulation)
- EWK and top (from simulation)

Two measurements:

- $\sin^2\vartheta_{eff}$ using A_{fb}
- Unfolded A_4 distribution

$\rightarrow$ for possible reinterpretation

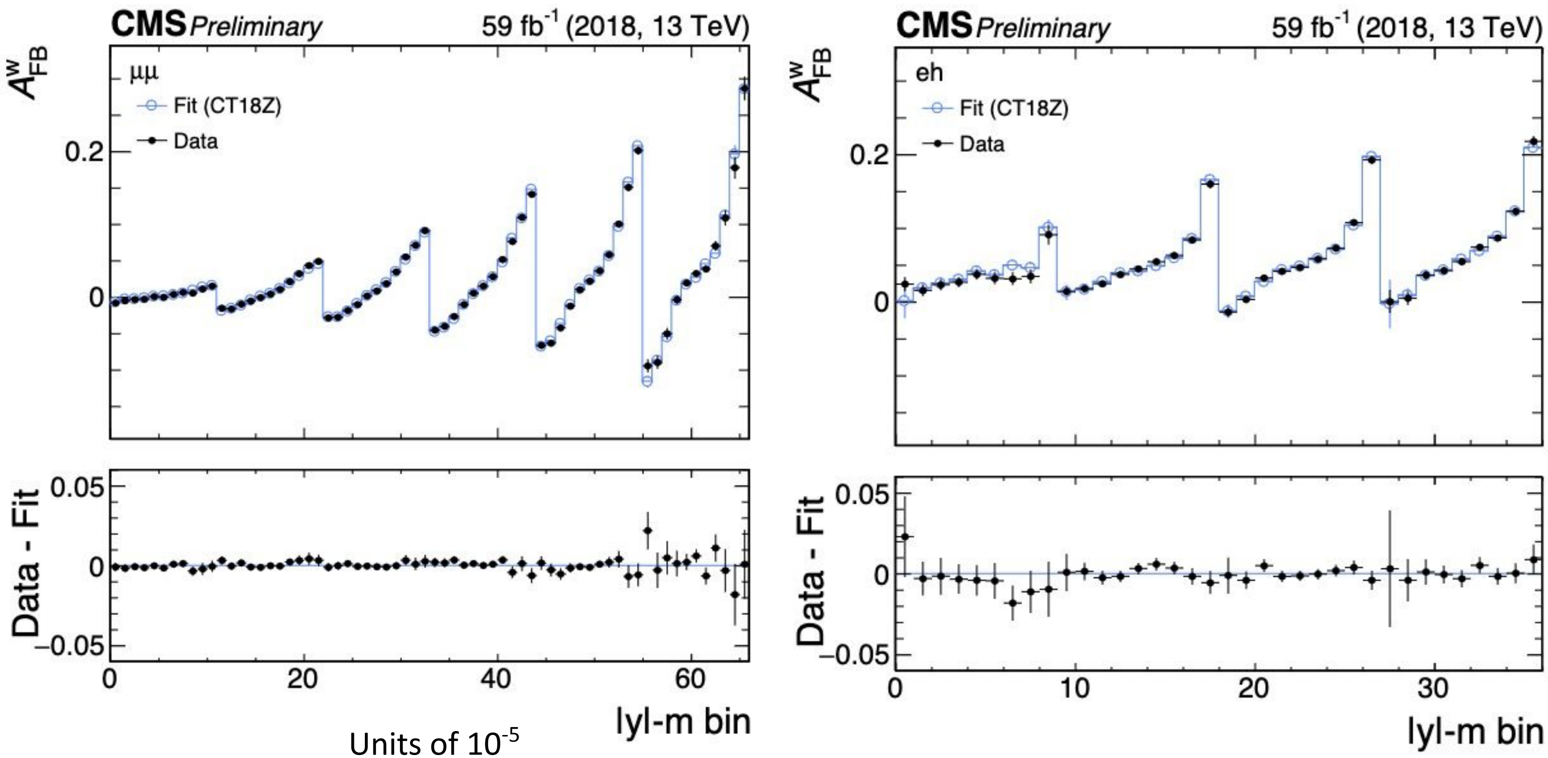




A_{fb} fit result

χ^2 simultaneous fit of $A_{fb}(y,m)$ in all year and channel categories

Good sensitivity from forward topologies

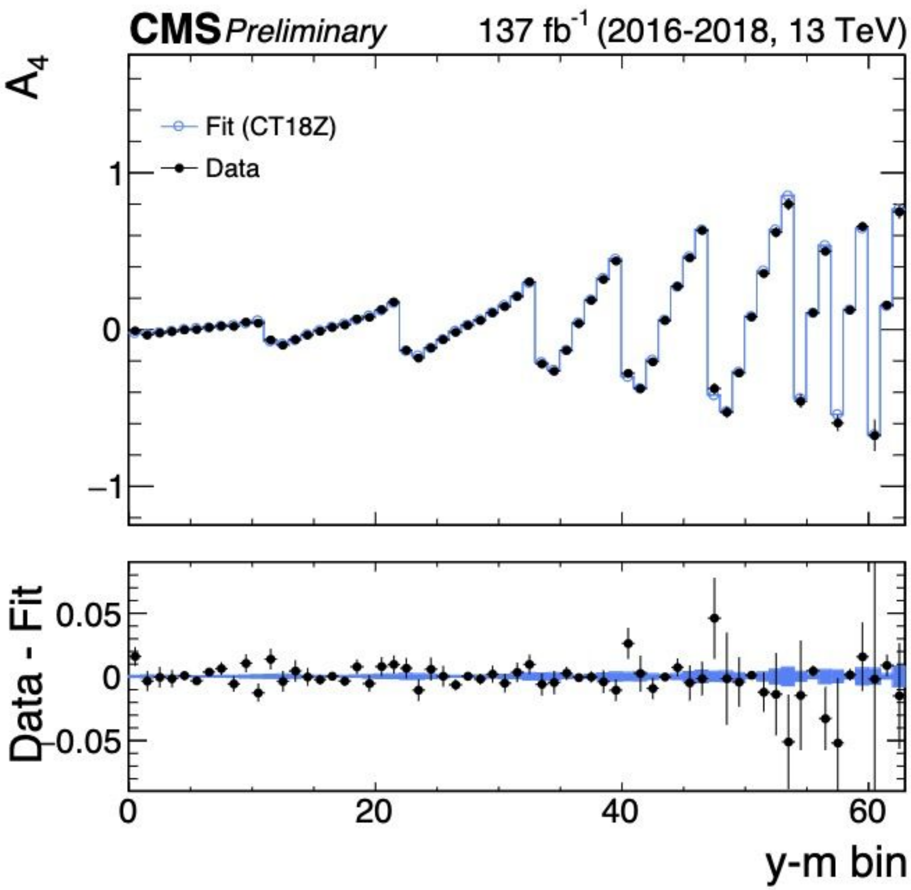


Units of 10^{-5}

ch	χ^2	nbin	p(%)	$\sin^2\theta^{\ell}_{\rm eff}$	$\pm$	σ	stat	exp	theo	pdf	mc	bkg	eff	calib	other
$\mu\mu$	241.3	264	82.7	23146	$\pm$	38	17	17	7	30	13	3	2	5	4
ee	256.7	264	59.8	23176	$\pm$	41	22	18	7	30	14	4	5	3	7
eg	119.1	144	92.8	23257	$\pm$	61	30	40	5	44	23	11	12	19	9
eh	104.6	144	99.3	23119	$\pm$	48	18	33	9	37	14	10	16	18	6
$\ell\ell$	730.7	816	98.4	23157	$\pm$	31	10	15	9	27	8	4	6	6	3

A_4 extraction and result

A_4 from fit on $\cos\vartheta$ distribution in rapidity and mass bins

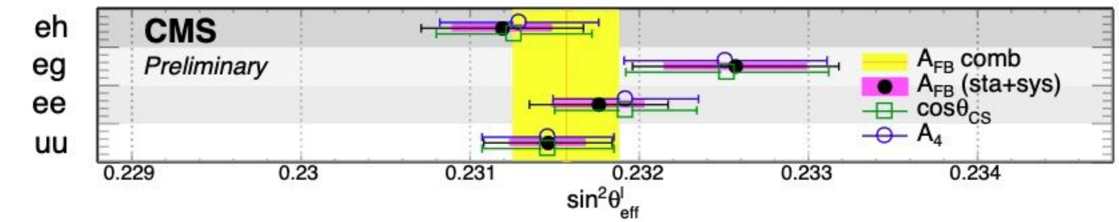


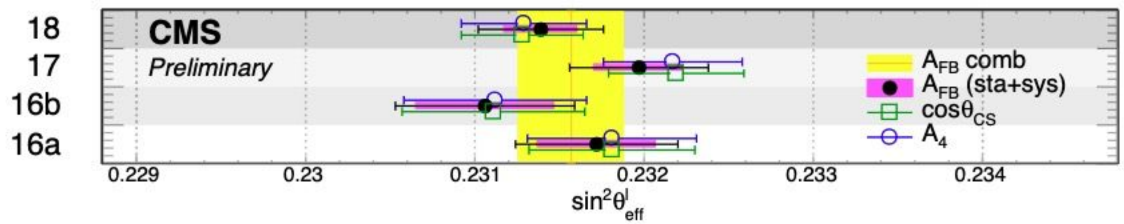
Extract $\sin^2\vartheta_{eff}$ simultaneously per year and channel

Channel	n(bins)	χ^2_{min}	p(%)	$\sin^2\theta^{\ell}_{eff}$	$\pm$	σ
$\mu\mu$	54	59.7	24.6	23146	$\pm$	39
ee	54	47.0	70.7	23192	$\pm$	43
eg	12	11.1	43.6	23251	$\pm$	60
eh	12	8.4	67.3	23129	$\pm$	47
$\ell\ell$	63	61.3	50.3	23155	$\pm$	32

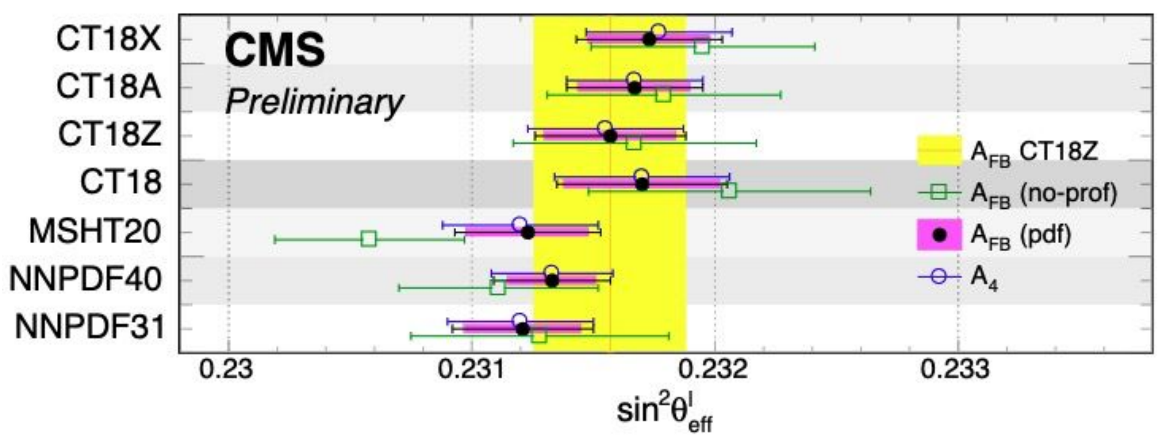
Compatibility checks

Good compatibility across channels and years

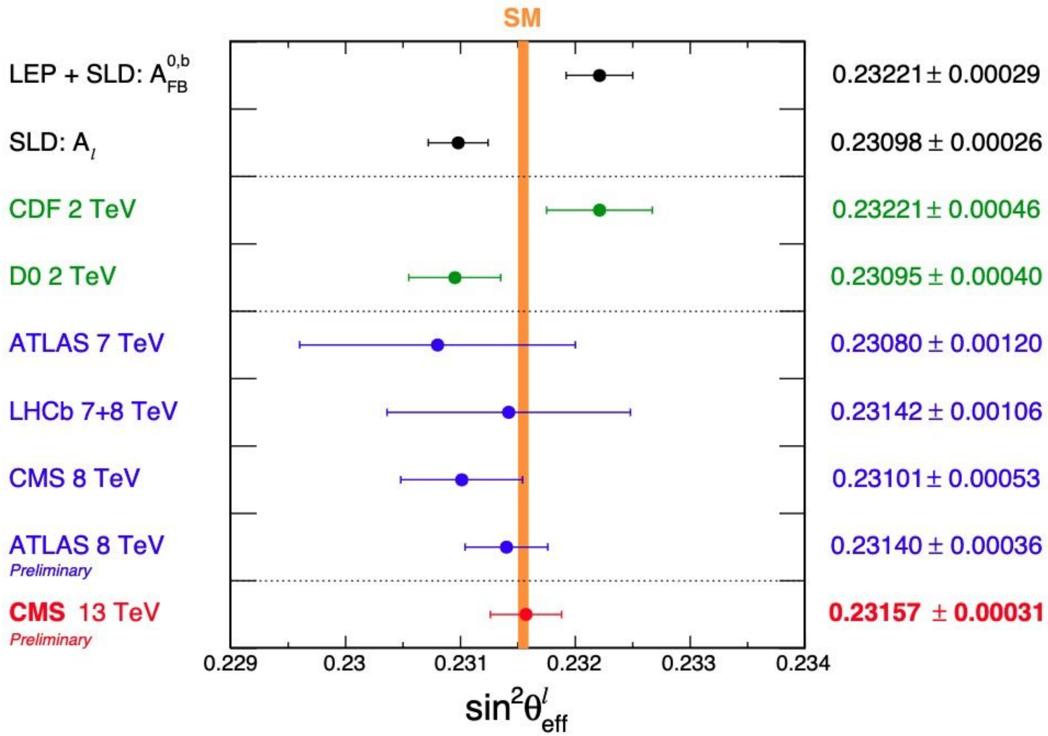




CT18Z PDF chosen before unblinding
→ based on best coverage of other variations



Results



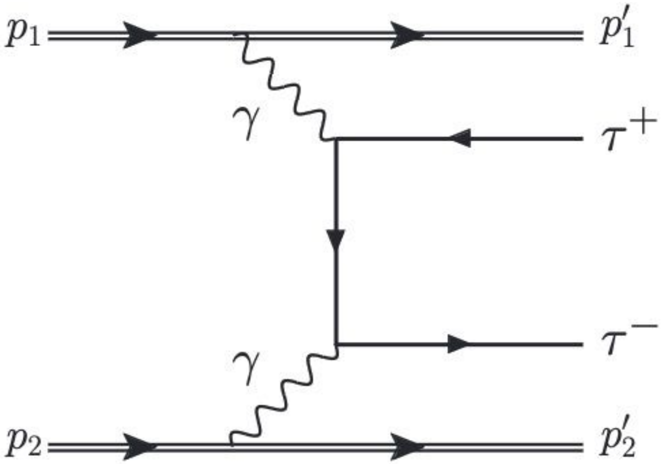
$$\sin^2\theta^\ell_{\rm eff} = 0.23157 \pm 0.00010(\text{stat}) \pm 0.00015(\text{syst}) \pm 0.00009(\text{theo}) \pm 0.00027(\text{pdf})$$

- Good agreement with SM and previous measurement
- Dominated by PDF uncertainties
- Most precise measurement at hadron collider!

$\gamma\gamma \rightarrow \tau\tau$ and g_τ-2

CMS-PAS-SMP-23-005

Intro



A photon-induced process from peripheral collisions

Goes as Z^4, so Pb-Pb enhancement

→ but at high transferred energy, p-p takes over

→ at very high energy one can look for fwd protons

Expect two back-to-back objects with minimal activity

→ Can use the number of tracks in the event as a discriminant

→ Can use topological variables to isolate this process

Contribution from non-elastic processes with partial (or total) proton dissociation

Analysis performed on the full run-2 on both leptonic (only different flavor) and hadronic τ decays

Tracks counting

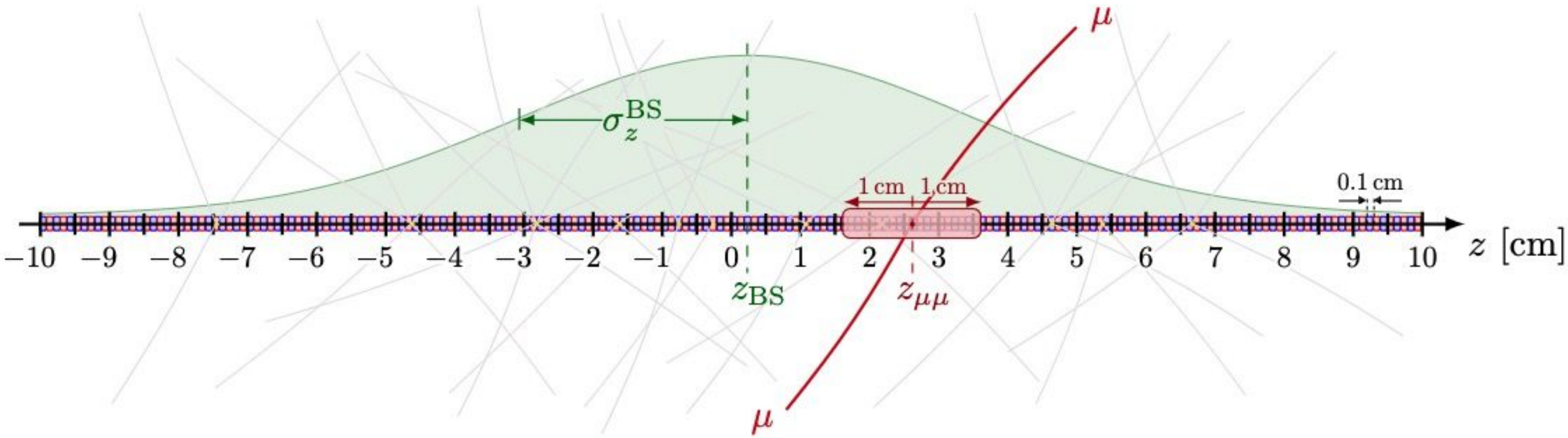
Define primary vertex as average z position of τs

Define N_{trk}

- $p_T > 0.5$ GeV and $|\eta| < 2.5$
- in a 0.1 cm windows around vertex

Two main corrections:

- PU: compare N_{trk} in DY data/MC in windows far from vertex
- Hard scattering: compare N_{trk} in DY data/MC around the vertex



[Semi-]dissociative contribution

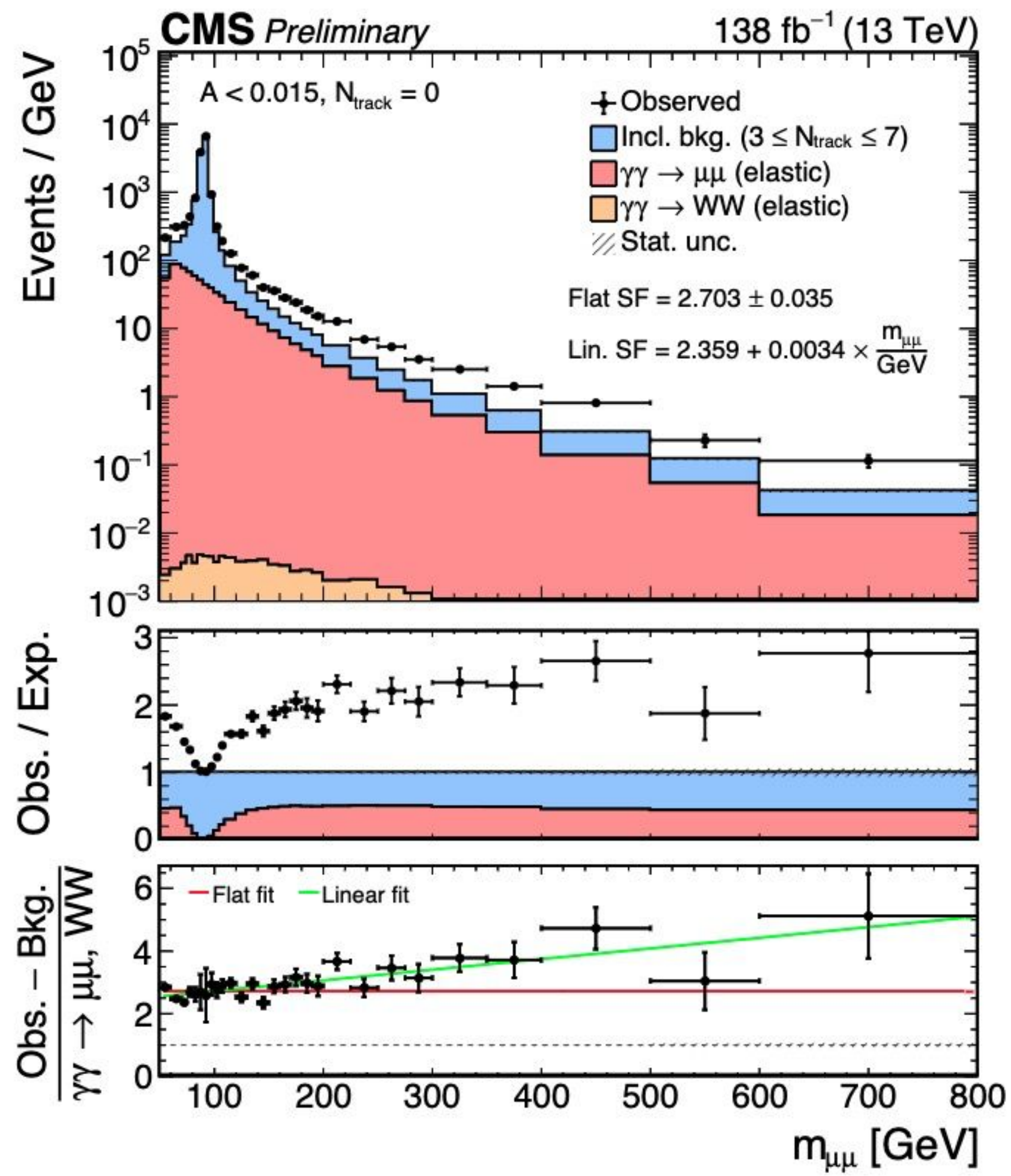
Contribution from dissociation of protons not negligible

- Rejected by topological cuts, but much higher cross section

Use $\mu\mu$ control region with signal selection

$\rightarrow$ Normalize Z peak to high N_{trk} region

Rescale elastic contribution outside the Z peak



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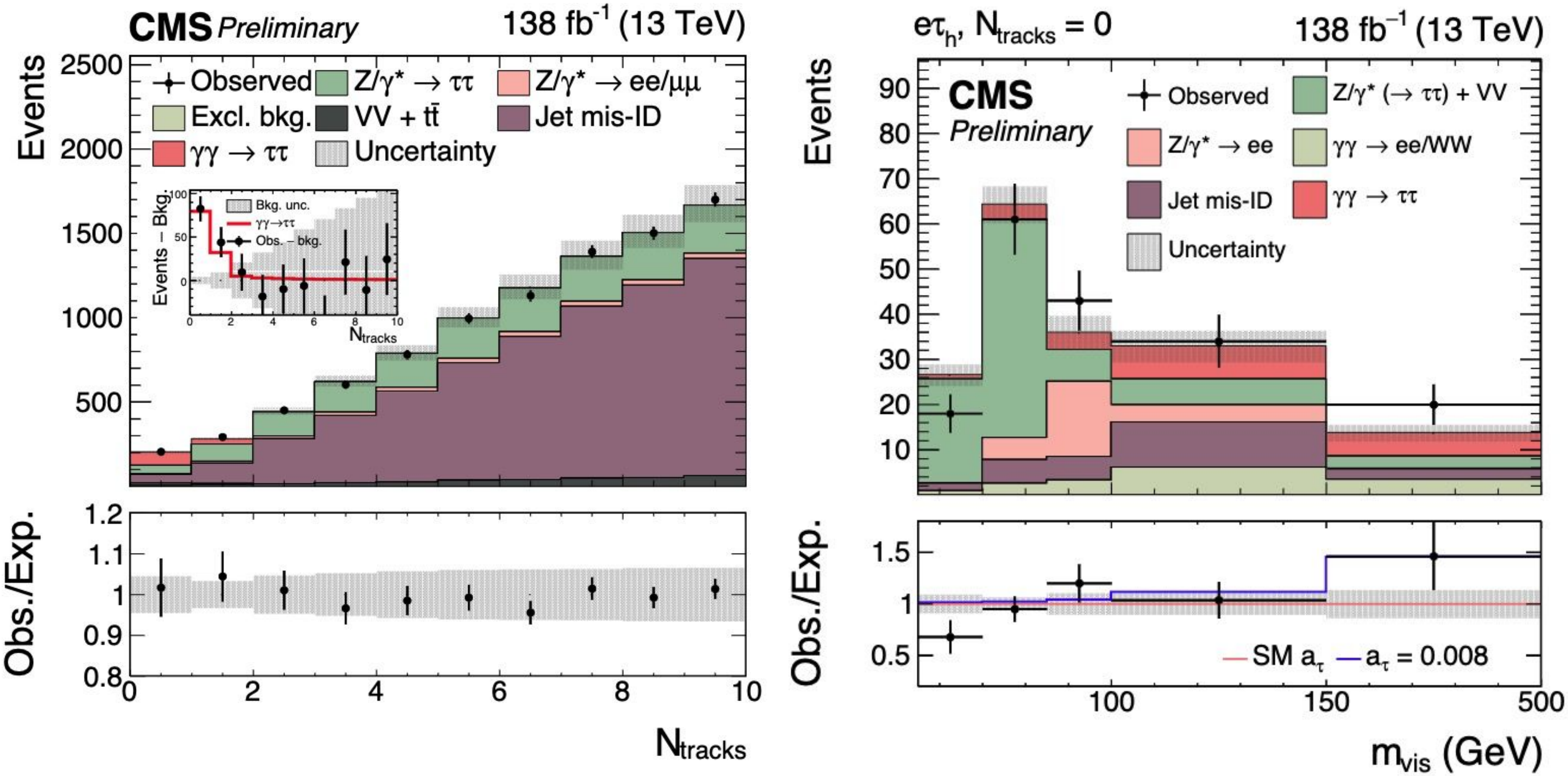
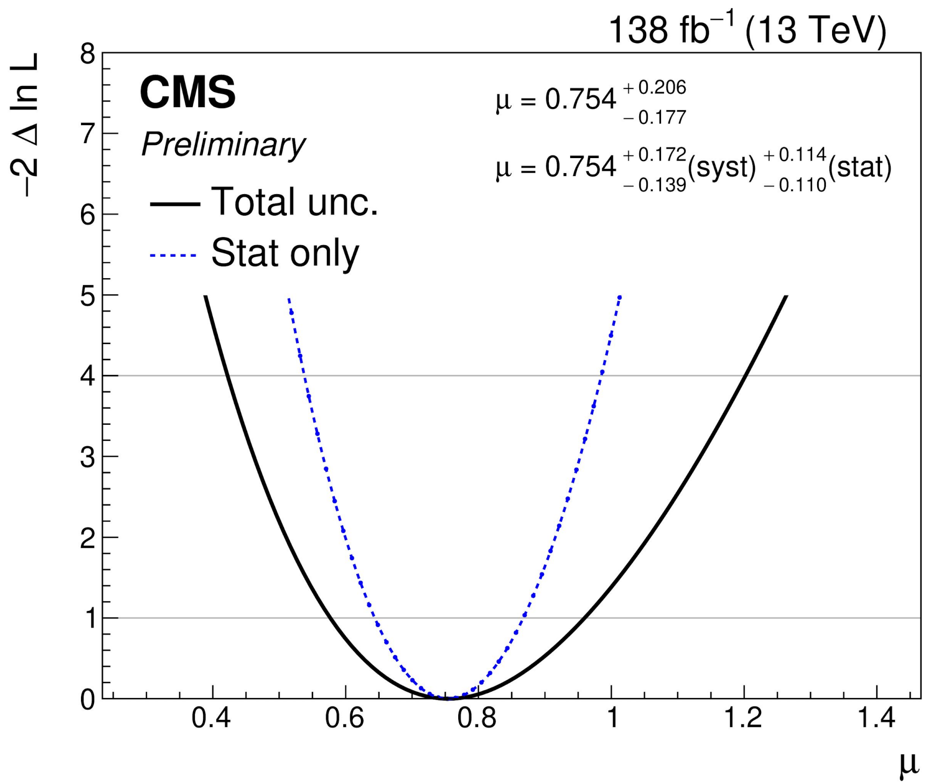


Main systematic uncertainties:

- Elastic rescaling
- UE/HS correction
- Hadronic tau ID

Observation of $\gamma\gamma \rightarrow \tau\tau$

First observation in p-p collisions!



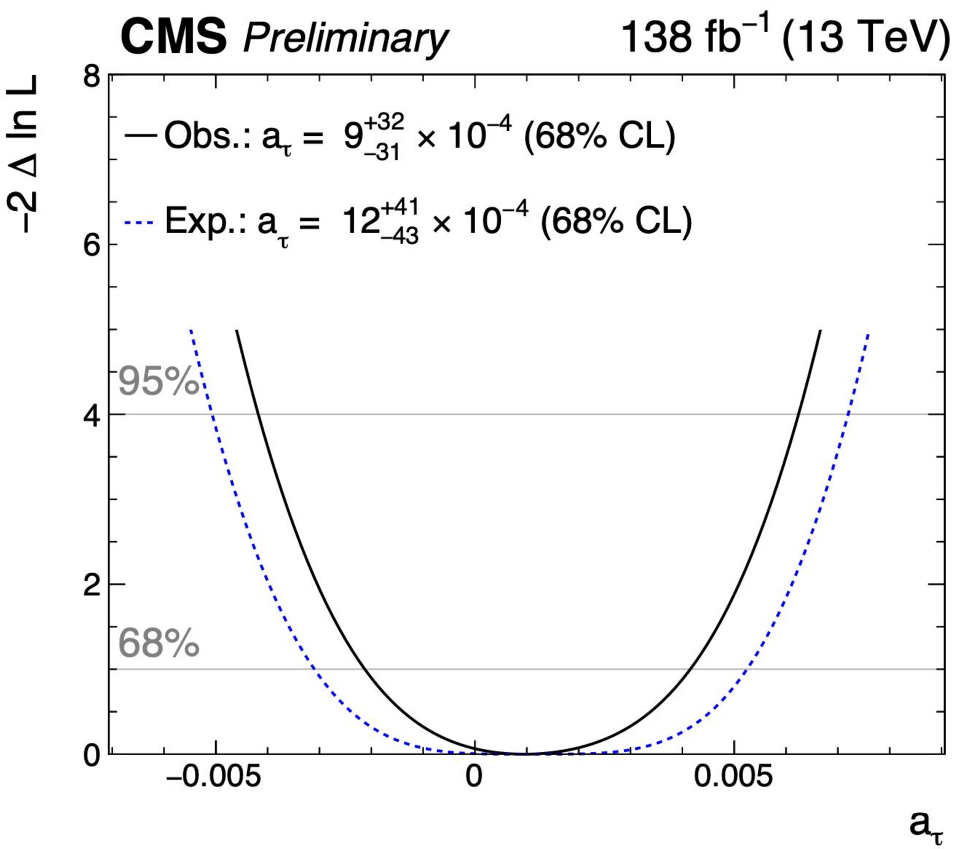
Signal strength for elastic prediction rescaled with our data-driven method

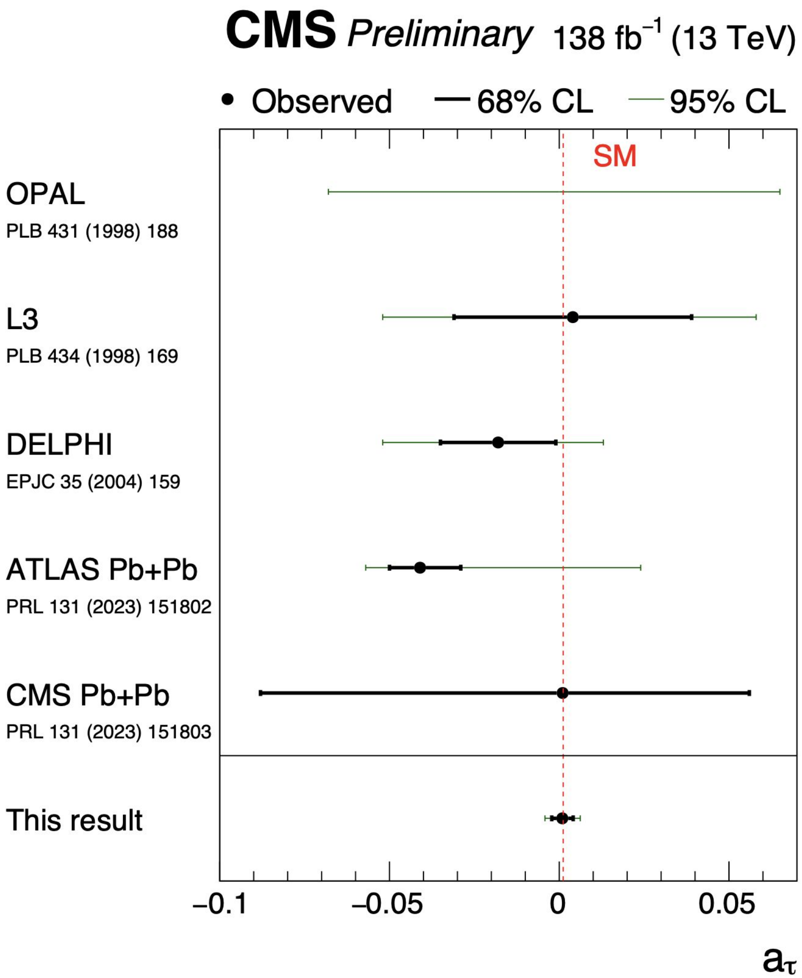
	Observed	Expected
$e\mu$	2.3 σ	3.2 σ
$e\tau_h$	3.0 σ	2.1 σ
$\mu\tau_h$	2.1 σ	3.9 σ
$\tau_h\tau_h$	3.4 σ	3.9 σ
Combined	5.3 σ	6.5 σ

Constraints on a_τ

Use invariant mass distribution to extract limit on anomalous dipole moment with a new EFT approach

$\rightarrow a_\tau$ modifies both shape and normalization





Uncertainty only 3 times the Schwinger term!

Conclusions

EWK precision measurements a staple of the LHC physics program!

Many key measurements are reaching (or beyond) the LEP precision era

- refine our techniques and understanding of our detectors to higher level

Feedback from theory fundamental to be able to push this precision even further

We are just at the beginning:

- completing the run-2 program
- many run-3 analyses in the pipeline